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14. ABSTRACT
The contemporary studies of the Kondo effect and heavy-fermion materials occur at the intersection of some of the most important phenomena in quantum condensed matter physics. First, they represent quantum magnetism in between the limits of local-moment and itinerant magnetism. Electronic systems in this intermediate regime are particularly tunable. Correspondingly, heavy fermions have emerged as a promising setting to study the physics of quantum phase transitions and unconventional superconductivity, which are relevant to a broad class of correlated quantum materials. Second, heavy fermion materials typically contain heavy elements, and there is an increasing

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Report Title

Final Report: Heavy Fermion Materials and Quantum Phase Transitions Workshop on Frontiers of the Kondo Effect

ABSTRACT

The contemporary studies of the Kondo effect and heavy-fermion materials occur at the intersection of some of the most important phenomena in quantum condensed matter physics. First, they represent quantum magnetism in between the limits of local-moment and itinerant magnetism. Electronic systems in this intermediate regime are particularly tunable. Correspondingly, heavy fermions have emerged as a promising setting to study the physics of quantum phase transitions and unconventional superconductivity, which are relevant to a broad class of correlated quantum materials. Second, heavy-fermion materials typically contain heavy elements, and there is an increasing recognition that their substantial spin-orbit coupling leads to new physics and correlated topological states. Third, the interplay between the localized and itinerant electrons connects the heavy-fermion systems to transition-metal compounds at the border of localization and itinerancy. Finally, the Kondo effect can also be studied in engineered materials, which are especially suitable for studying non-equilibrium physics. Research in the interconnected areas will contribute to the design and understanding of advanced materials that may impact on future technologies in energy, information and medicine. The workshop brought together top experts in these areas. It provided perspective about the existing research, and discussed the future directions of this exciting subject.

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Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The workshop took place in Houston, on the campus of Rice University. It lasted for two days, during December 10/11, 2013.

The workshop addressed frontier topics on the Kondo effect and quantum phase transitions in heavy fermion materials and related systems, a broad area which lies at the intersection of some of the most important phenomena in quantum condensed matter physics.

The workshop gathered a small group of top experts to discuss the status of the field, and to assess the opportunities for new physics. It started with two perspective talks, an experimental one by F. Steglich (MPI-CPfS, Dresden) and a theoretical one by P. Coleman (Rutgers. They emphasized current issues in the heavy-fermion field, as well as their place in the historical studies of the heavy-fermion materials.

The second session covered heavy-fermion quantum criticality, which in many ways is the most active subject in this field. The speakers were Hilbert von Lohneysen (Karlsruhe Institute of Technology), whose reported new materials and physics on heavy-fermion quantum criticality; Silke Paschen (TU Vienna) and Meigan Aronson, both of whom reported on new frontiers on the variety of quantum critical behavior. This was followed by a discussion on quantum criticality. This discussion session covered many open issues on quantum criticality. It was both focused and lively.

The third session addressed heavy fermion materials by design. Gabriel Kotliar (Rutgers) discussed his effort along this direction from ab initio correlated electron theory of electronic structure, and Brian Maple (UCSD) discussed routes to heavy fermion behavior in correlated electron materials. This was followed by an extensive discussion session on heavy fermion materials.

The fourth session dealt with Kondo physics in cold atoms. Han Pu (Rice) reported work on single impurity in quantum gases, and Eugene Demler (Harvard) addressed quantum criticality's in ultra cold atoms, with physics ranging from poltroons to orthogonality catastrophe to Kondo effect.

The fifth session was devoted to the spin-orbit physics and low dimensional systems: Z. Fisk (UC Irvine) reported recent studies on surface states in SmB6, G. Finkelstein (Duke University) on quantum dots coupled to leads with both electronic and dissipative bosonic bath. One of the co-organizers, D. Natelson discussed non-equilibrium properties of single-electron devices and nanoscale junctions. These were followed by a discussion session devoted to the general aspects of the Kondo physics in the context of spin-orbit physics, low-dimensional systems and non-equilibrium behavior.

The sixth session featured new insights that the quantum criticality has brought to the understanding of heavy-fermion superconductivity: Seamus Davis (Cornell) reported STM probe of heavy-fermion quantum criticality and superconductivity; Stefan Kirchner (Max Planck) discussed the role of quantum criticality on the superconducting condensation in heavy-fermion superconductors, and Collin Broholm (Johns Hopkins) discussed magnetic excitations of heavy fermion superconductors.

The workshop concluded with a wide-ranging talk by Joe D. Thompson (Los Alamos) regarding the connection between heavy-fermion systems and d-electron systems, and a summary discussion led by Q. Si which summarized the insights that have been gained in the field so far and the opportunities that exist for future progress.

The workshop was attended about 60 participants, including many graduate students and junior researchers from Rice University and other institutions.

By all accounts, the participants valued the workshop as highly successful in discussing both the recent progresses and major opportunities for the future, and in having all these taking place in a stimulating, open, and friendly atmosphere.

Technology Transfer